WF-101

# Wi-Fi Power Optimization Guidelines for Six IoT Devices using the SiWx917

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# Agenda

- Wi-Fi Power Optimization Guidelines for Six IoT Devices using the SiWx917

- **Introduction**
  - Six IoT Wi-Fi Devices
  - Power Optimization Challenges
- **Wi-Fi Power Optimization on SiWx917**
- **Power Optimization Guidelines (Six Examples)**
- **How to Learn More**

# Six IoT Wi-Fi Devices & Power Optimization Challenges

**IoT Sensor**

How to optimize TWT for a long battery life?

**Data Logger**

How to optimize sleep for long connectivity intervals?

**Cloud-connected Smart Device**

How to set up DTIM for low-latency applications?

**Connectionless Wi-Fi Tracker**

How to build a positioning tracker around Wi-Fi SoC?

**Neutral-less Switch/Dimmer**

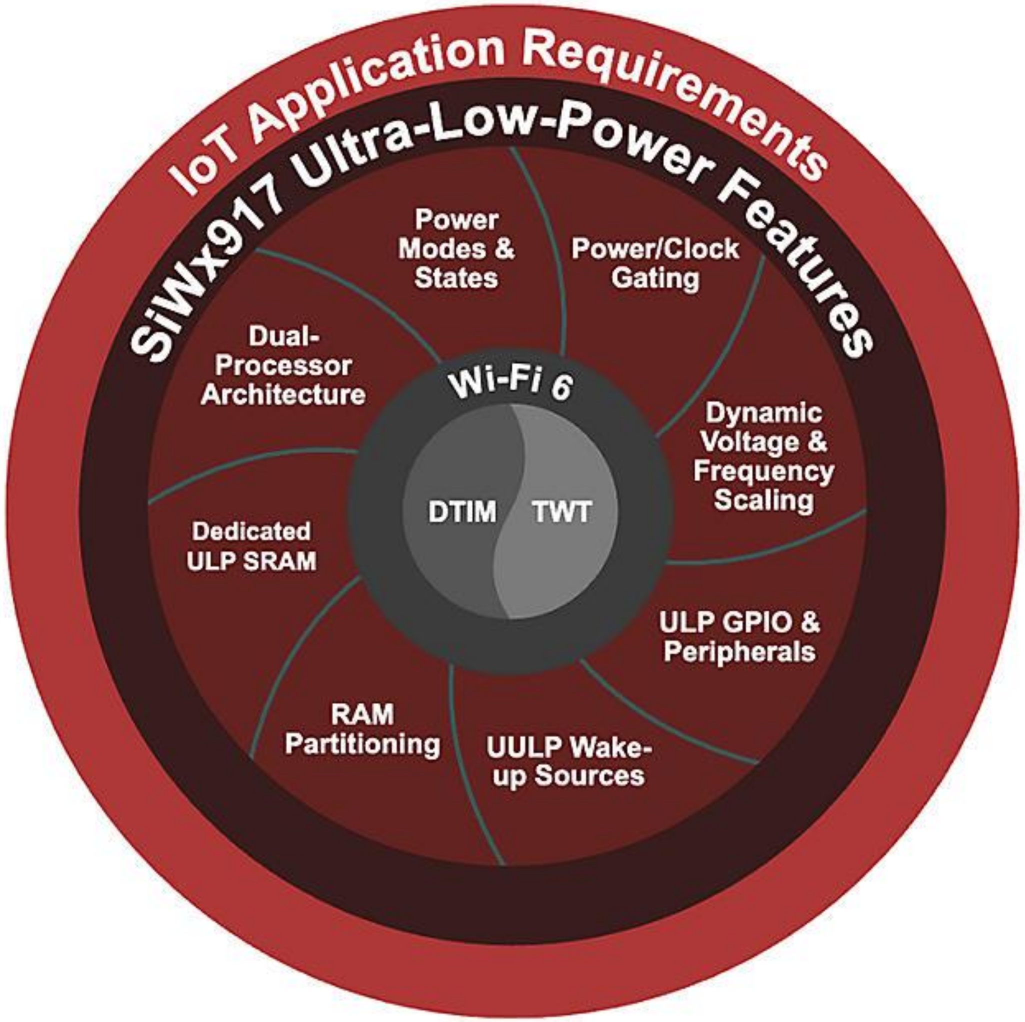
How to operate Wi-Fi below ceiling current?

**Solar-powered Wi-Fi Sensor**

How to minimize Wi-Fi peak power consumption?

# Wi-Fi Power Optimization Features on SiWx917

- **Dual-Processor**
  - Optimize application and wireless processing separately
  - Dedicated wireless processor offloads application MCU
- **Power Modes & States**
  - More possibilities to optimize energy consumption
- **Power/Clock Gating**
  - Turn on/off power on per block & power domain basis
- **Dynamic Voltage & Frequency Scaling**
  - Adjust CPU power and performance levels
- **ULP GPIO & Peripherals**
  - Collect sensor data, allowing the MCU and NWP sleep
- **Energy-Efficient RAM**
  - Regular and ultra-low-power SRAM portions
- **Wi-Fi power saving features**
  - Target Wake Time (TWT) – Wi-Fi 6
  - Legacy (DTIM) – Wi-Fi 4



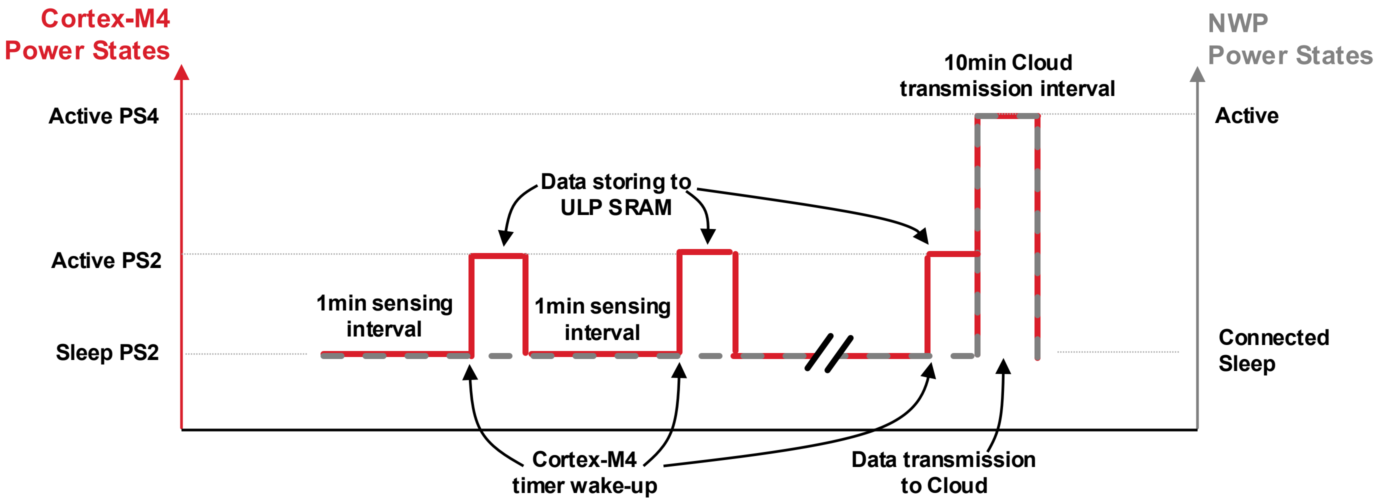
# IoT Sensor


- **Sleeps most of the time; reads and stores a sensor reading in short intervals**
- **Transmits the data to the cloud (e.g. MQTT server) periodically**
- **Examples: home weather stations, humidity and temperature sensors, oxygen sensors, occupancy sensors**
- **Data transmission is the most power consuming operation**
  - Data transmission frequency and duration must be minimized to maximize battery life

# IoT Sensor

## Power State Transitions

IoT Sensor, 60 sec sensing / connectivity interval




### Power State Transitions

- Use the Sleep PS2 mode with RAM retention for the MCU
- MCU goes to Active PS2 after wake-up, reducing wake-up time
- Using Shutdown PS0 mode would increase boot up time and power

### Sensing & Data Collection

- Use ULP and analog peripherals for sensing and data collection
- Maximize NWP and/or MCU sleep time

### Target Wake Time (TWT)

- Longer sleep intervals save more power
- TWT reduces collisions and retransmission
- If NWP and/or MCU sleep during sensing, you can extend the TWT interval

### Ways to Support Ad-hoc Sensor Interrupts Outside of TWT Service Period

1. Reduce TWT interval, if frequent transmissions are expected
2. Use TWT teardown/re-negotiation for large data packets (firmware update)

# Datalogger

- **Data loggers collect data with a predetermined interval**
- **The data is uploaded to the cloud periodically over Wi-Fi**
- **Very long interval of transmitting data to the cloud – several hours or even longer**
  - How to minimize sleep current consumption?



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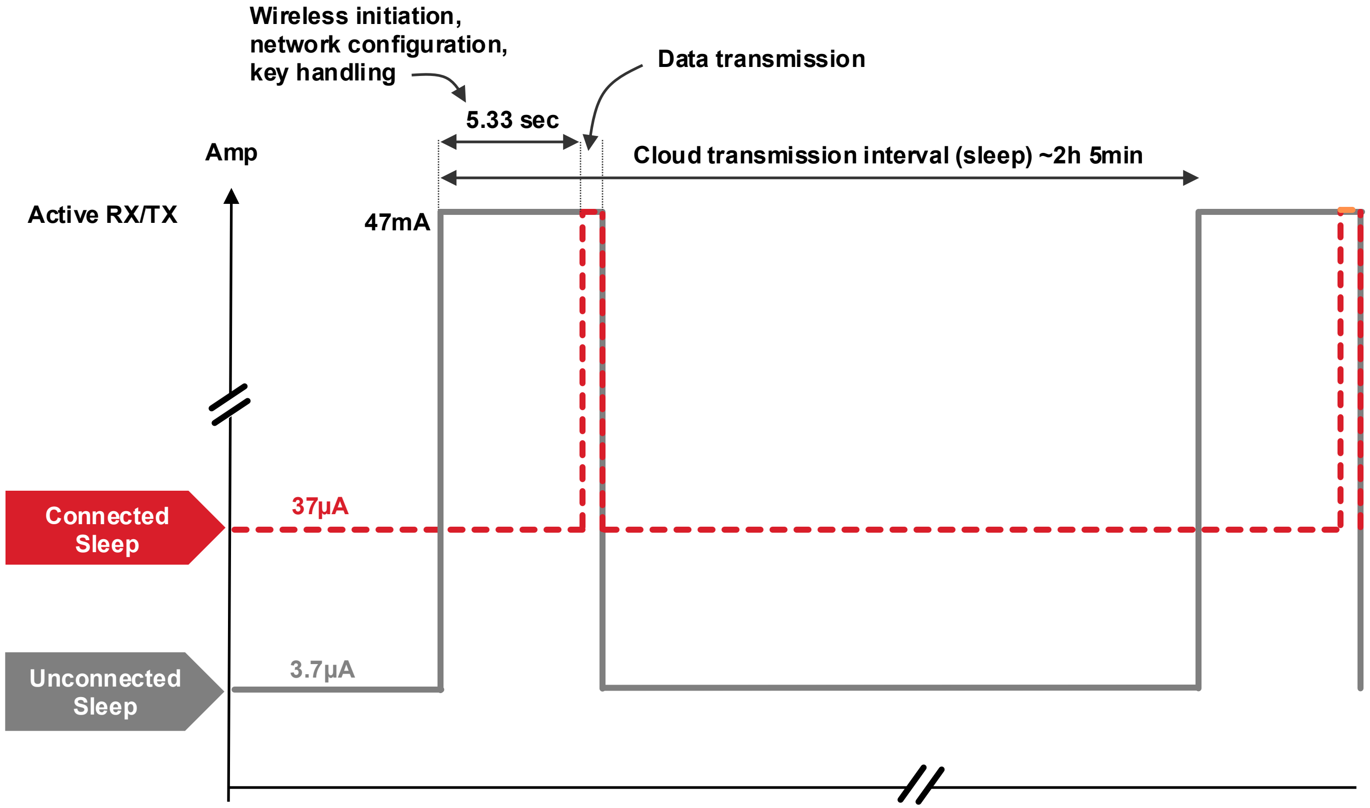
# Datalogger

## Connected Sleep

- Higher sleep current consumption
- No wireless initiation – Always connected
- AP and network context maintained in sleep
- Shorter active TX and RX duration
- Lower total energy consumption for connectivity intervals <u>below</u> 2h 5 min

## Unconnected Sleep

- Lower sleep current consumption
- Higher wireless initiation overhead
- Longer active TX and RX duration
- Lower total energy consumption for connectivity intervals <u>above</u> 2h 5 min




*The estimation is based on nominal power values of SiWx917.*
*Actual values will depend on local RF conditions, AP model, and other parameters*

# Cloud-Connected Smart Device


- **Always-on cloud connected smart devices require low-latency, bi-directional data communication**
- **The open/close request can come to a smart door lock from the cloud; the device must frequently wake-up and check if there is data on the Wi-Fi Access Point (AP)**
- **Some devices can have local sensor interrupts to wake-up and connect to cloud**
- **The wake-up interval must be short, e.g. one or a few seconds**
  - How minimize latency and power consumption?

# Cloud-Connected Smart Device

## Wake-up from the Cloud

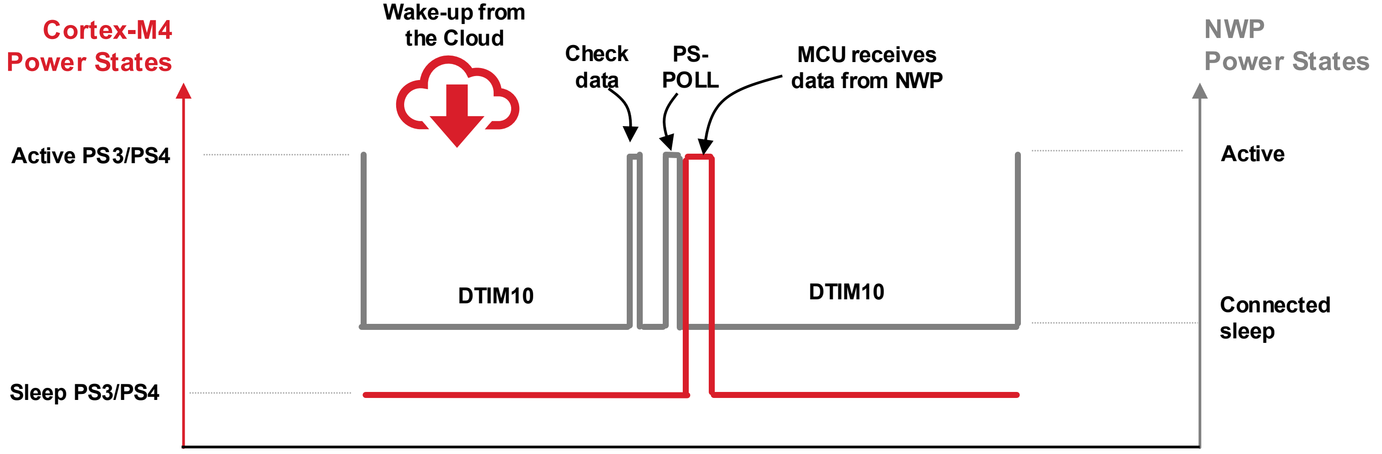
- **NWP wakes up to check AP for pending data per DTIM interval**
  - If data waiting – PS-POLL to retrieve
  - No data waiting – no data retrieval
- **Status reporting is recommended even if no data retrieved – ensures the device is working correctly**

## Local Wake-up

- **Alert/event is triggered by sensor interrupt**
  - Motion sensor detects intrusion
- **The device shall wake-up immediately and communicate the event to the cloud**

## Power State Transitions

Smart Device, Always-on Cloud-connected, DTIM10 (1 sec)



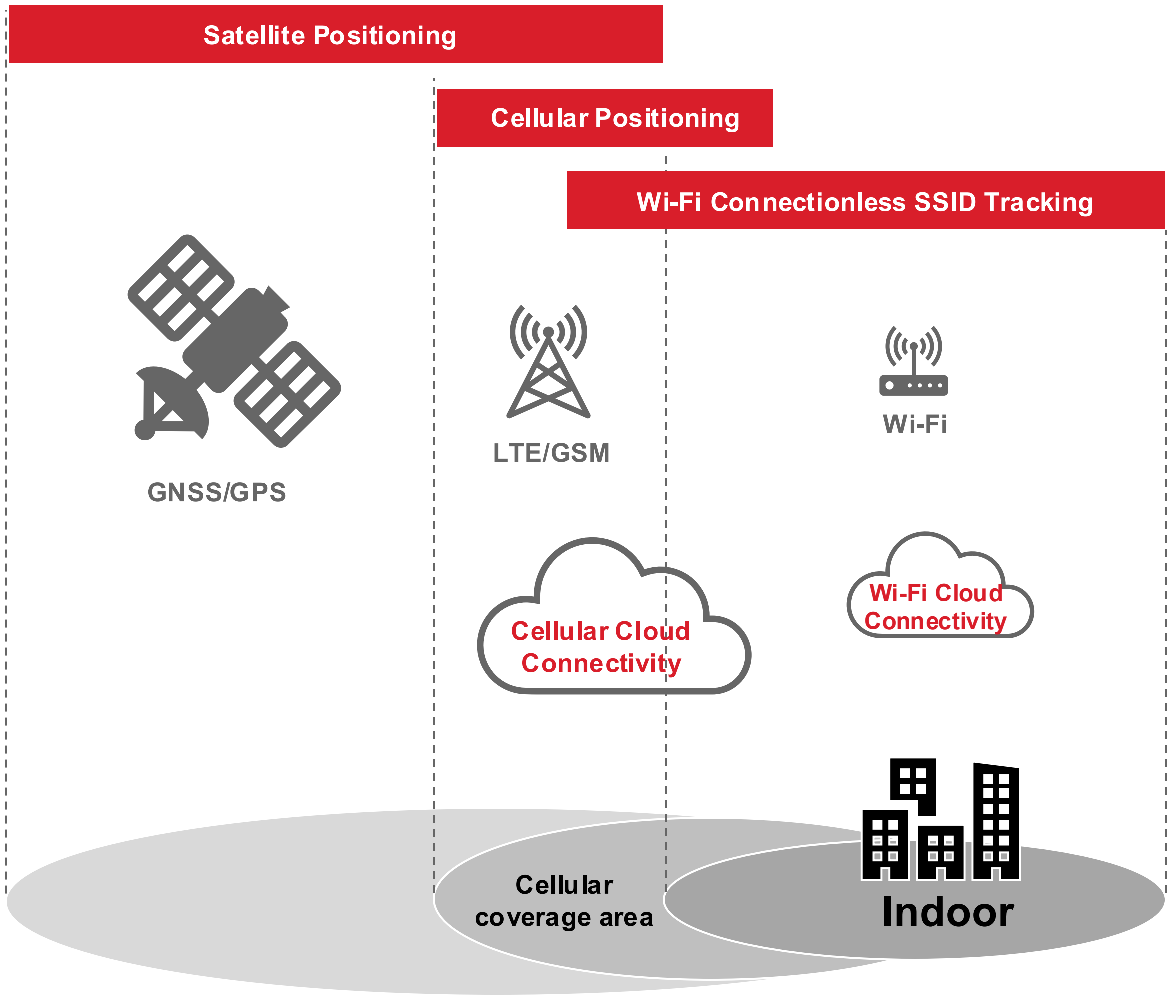

## MCU Power State Changes

# Connectionless Wi-Fi Tracker

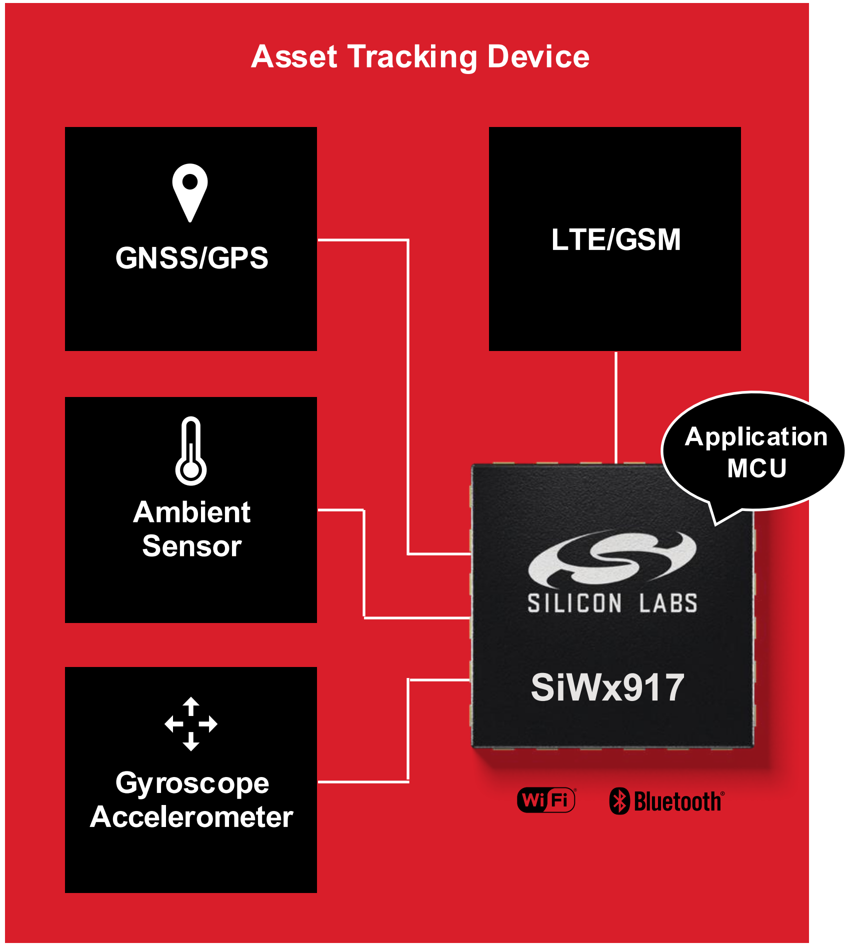

- Full-coverage asset tracking devices are true multi-technology systems
- LTE/GSM provides cloud connectivity and outdoor positioning in cellular areas
- GNSS/GPS gives accurate positioning everywhere except for indoors and dense high-riser areas
- Wi-Fi complements and augments cellular and satellite positioning; also provides more efficient indoor cloud connectivity alternative for cellular

# Multi-Technology Location Tracking

- **Wi-Fi positioning coverage**
  - Indoor positioning
  - Augments cellular positioning indoors and outdoors
- **Connectionless SSID tracking**
  - Wi-Fi client doesn't connect to the AP
  - Scans surrounding Wi-Fi APs
  - Retrieve information such as SSID and signal strength
- **Converts this to location using an external location database API**
- **Wi-Fi can also provide more efficient cloud connectivity method indoors**



# Tracker System Design Based on SiWx917 Wi-Fi 6 SoC




- **Wi-Fi 6**
  - Energy-efficient connectionless SSID tracking and cloud connectivity
  - Short time to cold-start
  - Fast capturing of SSIDs
- **Comprehensive, fully integrated wireless SoC**
  - Ultra-low-power, minimized system power, long battery life
  - Powerful application MCU (180MHz)
  - AI/ML accelerator
  - A rich set of peripherals
- **High GPIO count for system integration**
  - GNSS/GPS receiver, LTE/GSM, gyroscope/accelerometer, ambient sensor
- **Large memory**
  - 672kB SRAM, 8MB flash/PSRAM, interface for 16MB ext. flash/PSRAM
- **IP networking stack**
  - TLS and MQTT support simplify integration to cloud, ecosystems, location database
- **Bluetooth LE**
  - Smartphone commissioning and user interface
- **Regulatory certified modules available**
  - Integrated antenna and worldwide Regulatory certifications

**Saves BoM – No Separate MCU**



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# Neutral-less Wi-Fi Dimmer Switch

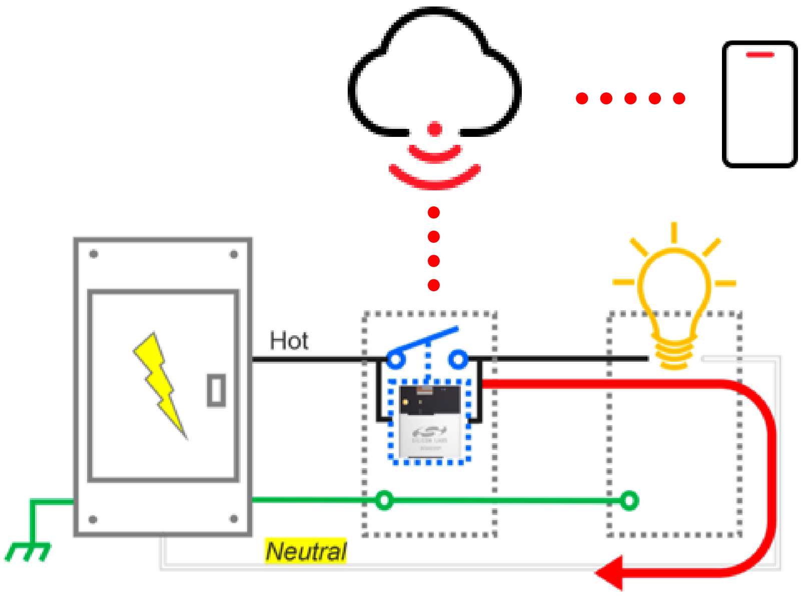
- **Some old houses lack the neutral wiring needed for light-controlling switchboxes**
- **Neutral-less smart dimmers and switches can operate without the neutral wire**
  - Wi-Fi is challenging in neutral-less installations due to high power consumption
- **The SiWx917 is the first MCU to enable neutral-less operation on a *Wi-Fi* smart dimmer switch**
- **Thanks to its ultra-low power consumption, you can develop retrofit Wi-Fi switches and dimmers that do not need the neutral wire**

Silicon Labs neutral-less smart dimmer switch demo and reference design kit

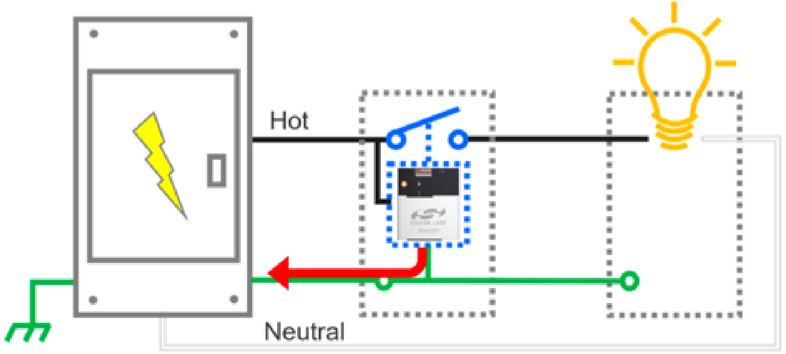
 

# Neutral-less Challenges and Opportunities

- **A neutral-less dimmer switch is a complex application because of two opposite working conditions**
- **The AC-DC converter of the dimmer must operate in two different scenarios**
  - When the light is **off**, the dimmer shall consume very little power to avoid lightbulb flickering (applies to LEDs)
  - When lightbulb is fully **on**, the voltage across the dimmer shall be theoretically zero, and the current is high.
    - This is not possible as the dimmer itself needs some power
- **Wi-Fi solution based on SiWx917**
  - Ultra-low current consumption meets both scenarios
    - Extremely efficient associated standby current enables light control from the cloud
  - BoM saving
    - Integrated MCU for TRIAC control
    - Integrated ACMP for Zero-Cross Detection



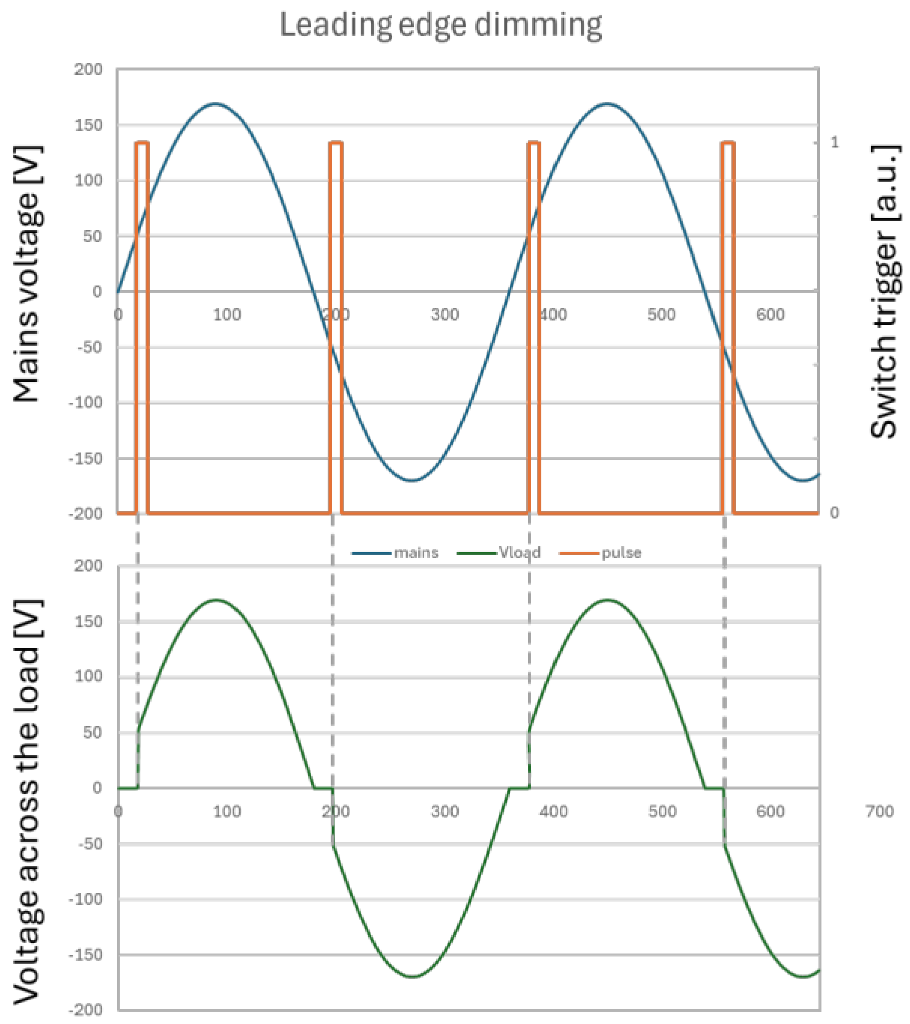

**Load current path**



# Solving the Neutral-less Wi-Fi Challenge

- **Reserve a fraction of the sinewave to power the dimmer itself when the switch is open**
  - the maximum power provided to the light is reduced
- **A neutral-less dimmer switch can be implemented using an AC-DC converter, which charges a storage capacitor**
- **The capacitor acts as reservoir for a second stage step-down converter, which powers the SiWx917 and can provide bursts of short-lived high-value currents at a regulated voltage**
- **The voltage of the storage capacitor can vary a lot, and it is slowly replenished when the circuit is idle (i.e. outside radio operations)**
- **To keep the charging current low, it might take several sine wave cycles to fully charge the storage capacitor (see the figure below).**

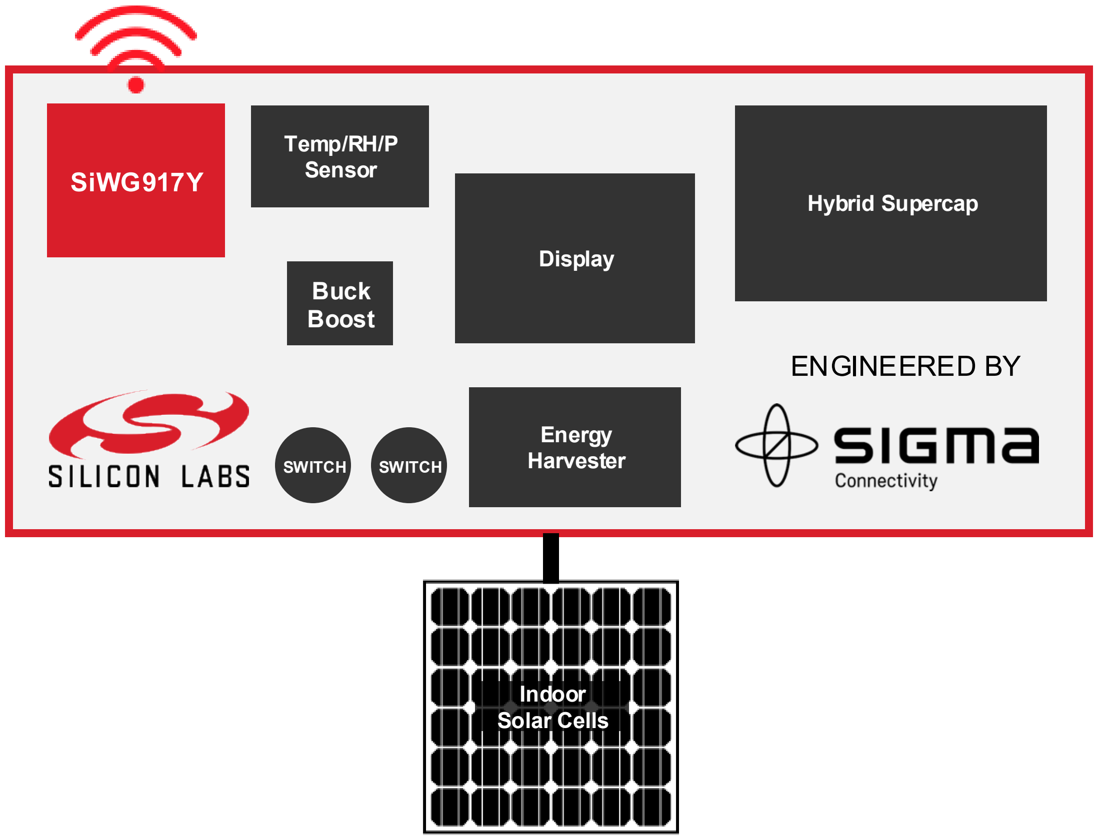


# Solar-Powered Wi-Fi Sensor


- Wall-mounted Wi-Fi ambient sensor that doubles as a notepad
- Running on solar power (indoor)
- Sensor readings are fetched every two minutes, the on-board display is updated, and the readings are sent to the cloud over Wi-Fi
- Energy harvester circuit charges the super capacitor as long as there is a sufficient level of illuminance
- The system needs a power consumption hysteresis strategy

# Solar-Powered Wi-Fi Sensor

- **Wi-Fi**
  - SiWG917Y module with antenna
- **Solar Cells**
  - Epishine indoor solar cells with nine 6-cell units
- **Energy Harvester**
  - e-peas ambient energy management circuit
- **Buck Boost Converter**
  - Texas Instruments
- **Hybrid Supercapacitor**
  - Vinatech hybrid super capacitor
- **Display**
  - Mikroe eINK click display adapter
  - Waveshare E-paper display
- **Temperature Sensor**
  - Bosch multi-sensor




**Power Budget of the System:**
- Dimensioned for 200 LUX illuminance for 8 hours a day
- Harvesting capacity of the solar cells is ~6mW per $cm^2$
- Total solar cell area $225cm^2$ is estimated to yield 10,800 mWh



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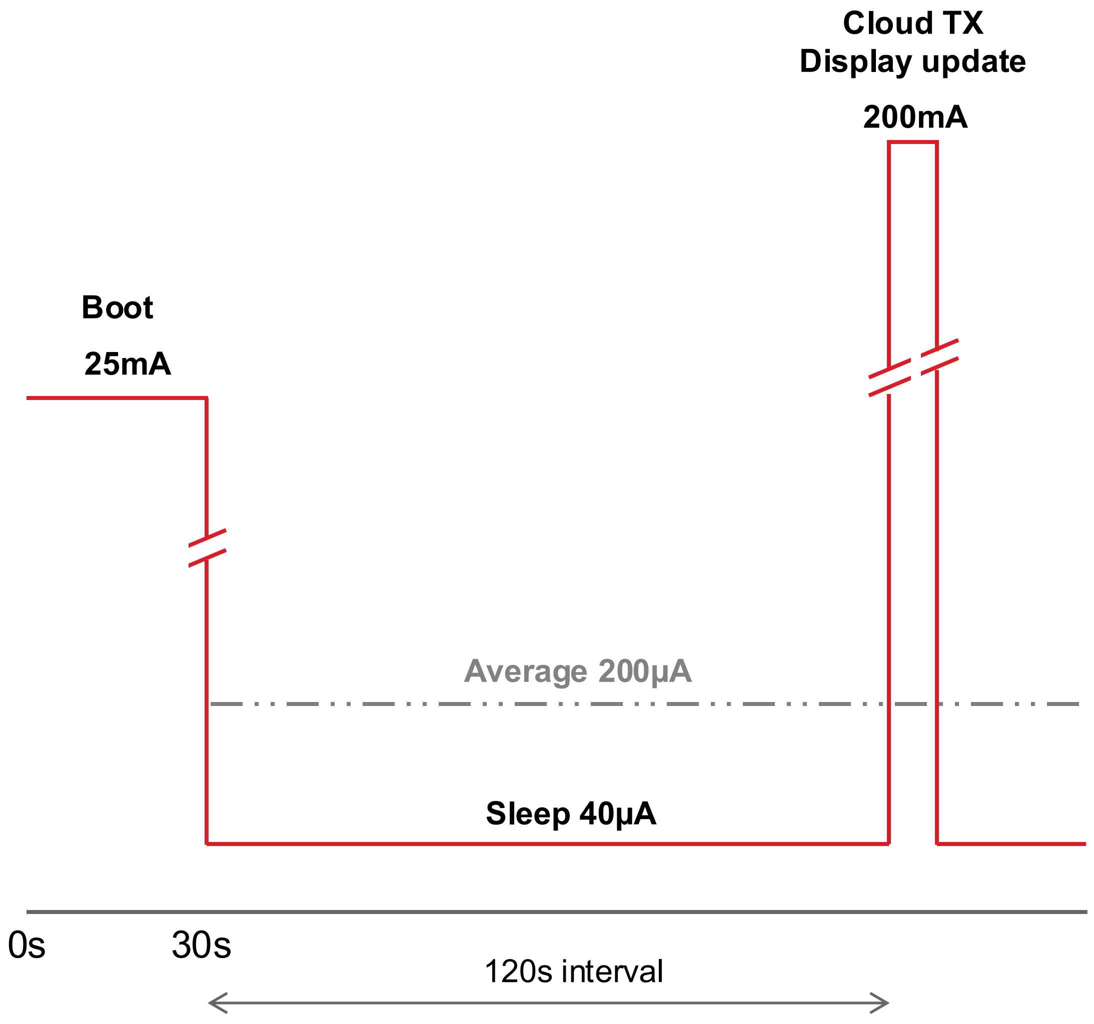
# Wi-Fi Operation

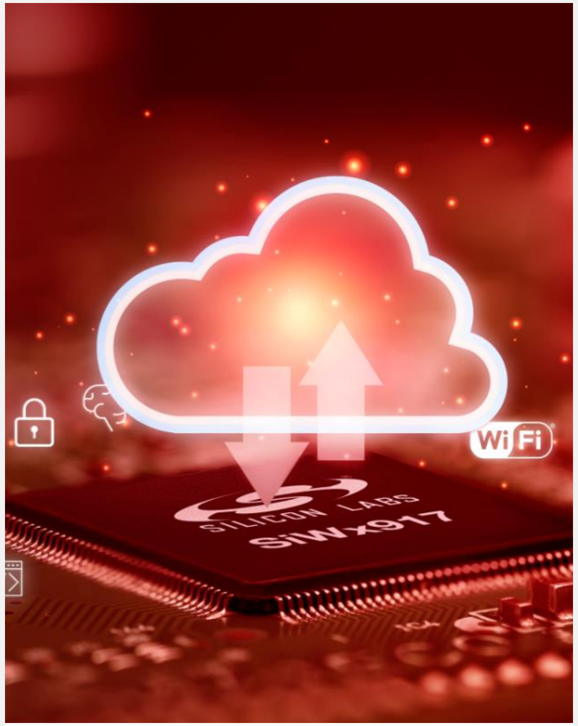
- **Power during initial Wi-Fi connection to AP**
  - ~25 mA, 30 sec after device wake-up
- **Retries are limited to avoid draining the harvested energy during connection outages**
- **Instantaneous peak system power: ~200 mA**
  - During Wi-Fi cloud transmission and display updates every 120s
- **Average current consumption without boot**
  - ~200µA

## Wi-Fi Settings

- TWT RX latency: 60 sec
- Device average throughput: 20 Mbps
- Estimated extra wake duration: 0%
- TWT tolerable deviation: 10%
- TWT default wake interval: 1024 msec
- TWT default wake duration: 8 msec
- Max beacon wake up after service period (SP): 2 (the number of beacons after the SP completion for when the NWP wakes up to listen for pending RX)
- TCP keep alive time: 240 sec

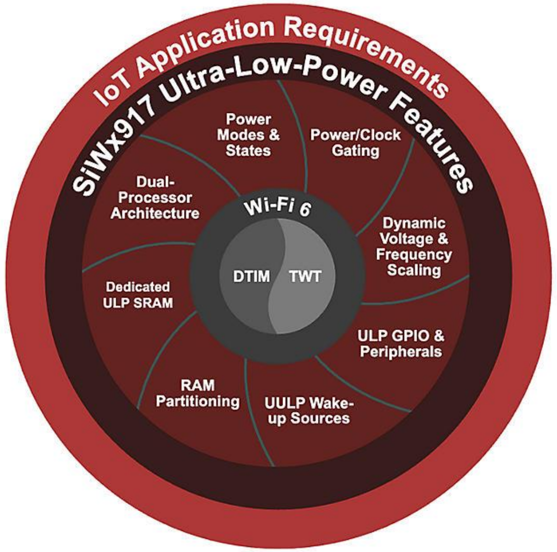


# Learn More about IoT-Optimized Wi-Fi



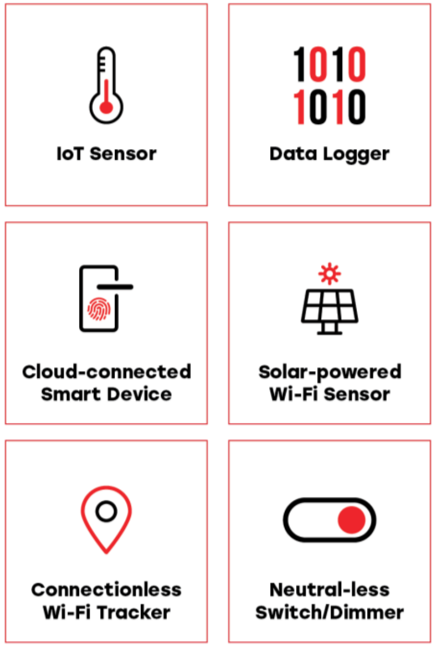

WHAT IS IT?

[IoT-optimized Wi-Fi is about more than just low power consumption]



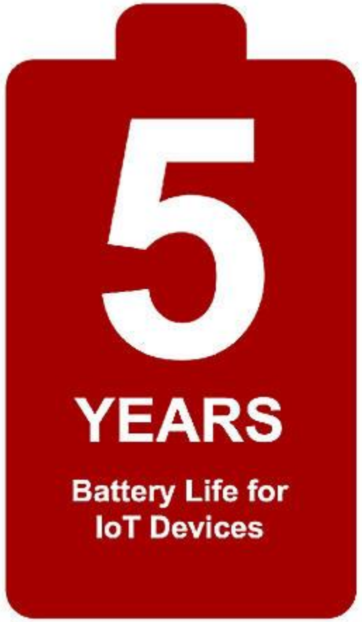

OPTIMIZATION

[Explaining the SiWx917 Low-Power Wi-Fi Features for IoT Product Developers]




SIX EXAMPLES

[Wi-Fi Power Optimization Examples for Six IoT Devices]




TEST RESULTS

[SiWx917 Wi-Fi interoperability & power consumption test results]

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